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AUTHORITY

USNWC ltr, 17 Apr 1979

NWC TP 5174

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Summary of Selected Worldwide Temperatures in Explosive Hazard Magazines

by

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Propulsion Development Department

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Naval Weapons Center
CHINA LAKE, CALIFORNIA • FEBRUARY 1972

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ABSTRACT

Minimum and maximum temperatures (385,221 data points) from explosive hazard storage magazines located at Yuma, Arizona; Subic Bay, Philippines; and Fort Richardson, Alaska are used to construct cumulative distribution curves. These distribution curves show the probability that ordnance, stored in these magazines, will reach any given air temperature. They allow an objective judgment to be made on maximum and minimum earth-covered storage magazine temperature specifications.

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Naval Weapons Center

AN ACTIVITY OF THE NAVAL MATERIAL COMMAND

W. J. Moran, RADM, USN .... Commander
H. G. Wilson .... Technical Director

FOREWORD

This work is part of a continuing effort to determine the overall storage temperature environment for naval weapons. The work covered in this report was funded under AirTask F00-311-008 Environmental Criteria Determination with support from Task W1174 (Harpoon Project) and Task W1162 (FAE Project).

This report has been reviewed for technical accuracy by Warren W. Oshel.

Released by
C. MAPLES, *Head*
Quality Assurance Division
1 February 1972

Under authority of
G. W. LEONARD, *Head*
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CONTENTS

INTRODUCTION

The Naval Weapons Center (NWC), China Lake, Calif., has been assigned the task of determining the overall storage temperature environment for Naval weapons. As a first step it was assumed that magazine storage time constituted the major portion of the life cycle of weapons such as projectiles, bombs, and missiles. The temperature records for igloo and storehouse structures as required by Ordnance Publication OP-5, Volume 1 are being obtained on a continuing basis from the majority of U.S. Navy storage facilities worldwide. Selected U. S. Army installations are also contributing magazine temperature data for this project.

The data received from the storage facilities consist of maximum and minimum air temperatures taken inside the storage structures of interest. The temperature reading period can vary from daily to once or twice a month, depending upon the facility.

Six reports of a continuing series entitled "Storage Temperatures of Explosive Hazard Magazines" (Ref. 1 through 6), containing magazine storage temperature summaries and plots of monthly average maximum and minimum temperatures over the period of data coverage, have been published. These reports provide the basic information for this report. Additional data have been obtained since publication of the six reports, and have been included in the data reported herein to provide a larger statistical sample. Information from 12 years of records in a desert area, 7 years in a tropical area, and 11 years in an arctic area is included.

Although the data presented in Ref. 1 through 6 accurately define an exposure pattern in statistical terms, these reports do not present an overall picture integrating data from the many geographical locations. Since the purpose of any environmental endeavor is to provide information in a form that is usable to the design engineer, this report presents an attempt to place information from representative stations into an overall context. This is accomplished by using the data to plot curves that identify (for covered storage in this case) the probable duration that any piece of ordnance will be subjected to any given temperature range during a year's time span.

The data presented in Ref. 1 through 6 indicate that the three storage locations selected exhibit the most severe temperatures in the present formalized complex of U.S. Armed Forces logistics. Unpublished data from the United States Army European Command and Commander Naval Forces, Europe (COMNAVEUR) storage facility records indicate that more severe temperatures are not experienced in Europe. The work reported herein is biased toward the extreme temperatures recorded, since it is these conditions that can cause damage to stored weapons rather than the more moderate temperatures experienced in temperate zones.

INSTRUMENTATION AND DATA RETRIEVAL

The magazine temperature data were obtained through the use of "horseshoe" maximum and minimum mercury thermometers. These thermometers are equipped with metal "tattletale" devices that float on the mercury and remain at the highest and lowest temperature positions reached during the measurement period. The raw data are recorded on summary sheets of the maximum and minimum temperatures organized by magazine area, magazine type and the date of the readings. The information on the summary sheets is transferred onto IBM punch cards for computer input. The computer is then used to plot the data of interest. A more detailed description of the data handling is given in Appendix A.

The horseshoe thermometers are located in the magazines so that they can easily be read by the ordnancemen; usually they are mounted on the inside wall of the entrance. This is the only wall that is not insulated in the earth-covered magazines. Measurements taken by NWC personnel have shown that the air temperatures in central parts of the structures are much more constant and moderate (~70°F) than the measurements from the horseshoe thermometers. Therefore, it is believed that the data are conservative since (1) the non-insulated wall would be most thermally active, (2) the sequence of ordnance placement in the magazine would preferentially be from the back wall towards the entrance, and (3) the thermal mass of the ordnance would tend to dampen the extreme values. Results of some preliminary measurements that were taken at various locations within an earth-covered magazine at NWC are given in Appendix B.

DATA SOURCE, SAMPLE SIZE, AND DATA REDUCTION

The data were taken from NWC TP 4143, Parts 1, 2, and 4 (Ref. 1, 2, and 4). The Yuma data represent the high temperature extremes, the Subic Bay data represent the temperatures encountered in the tropics, and the Fort Richardson data represent the low temperature extremes. These data are summarized in Table 1. It is concluded that the probability of constructing any sizeable ordnance storage complex in geographical areas with more severe temperature environments is low.

TABLE 1. Data Summary by Location and Magazine Type.

Storage location	Magazine type	Length of time, months	Number of data points	Temperature, °F	
				Maximum	Minimum
Yuma Proving Ground	Earth-covered	146	35,394	117	25
Subic Bay	Earth-covered	85	39,950	100	60
Fort Richardson	Earth-covered	137	2,810	66	18
	Non-Earth-covered	112	2,880	80	-9

RESULTS

The cumulative distribution curves for the minimum and maximum magazine air temperatures for Yuma, Arizona; Subic Bay, Republic of the Philippines; and Fort Richardson, Alaska are plotted in Fig. 1 through 5. From these figures, one can estimate the duration, of time in percent, that the air temperature is less than 60°F, greater than 100°F, between 60 and 100°F, etc. For example, the duration, of time in percent, that the air temperature is greater than 110°F at Yuma is almost zero (actually 0.13% or less than 12 hours per year); that the air temperature is greater than 67°F and less than 85°F at Subic Bay is 65%, etc. If it is assumed that it is equally likely that an ordnance item is stored in the desert, the tropics, or the arctic, the percentage of time that the ordnance is expected to be subjected to 110°F or higher is almost zero (actually 0.089% or less than 8 hours per year). Appendix C gives a description of how the curves were constructed.

Figure 5 represents all of the Yuma, Subic Bay and Fort Richardson maximum and minimum magazine storage air temperatures. The majority of the data are air temperatures between 80 and 90°F. This does not reflect the air temperatures of all magazine sources, but an averaging of desert, tropic, and arctic data from the three selected stations. The majority of the air temperatures from all storage magazine sources would center around 70°F. This is because the majority of the world's magazine storage sites are in the temperate zones of the world, not the desert, tropics, nor the arctic.

Since the temperate zone magazine data are not represented in Fig. 5, the middle temperature range (40-90°F) is not representative. Also, the omission of these data results in an indication of a higher percentage of temperature duration at the more extreme temperatures (<40 and >90°F) than actually occurs.

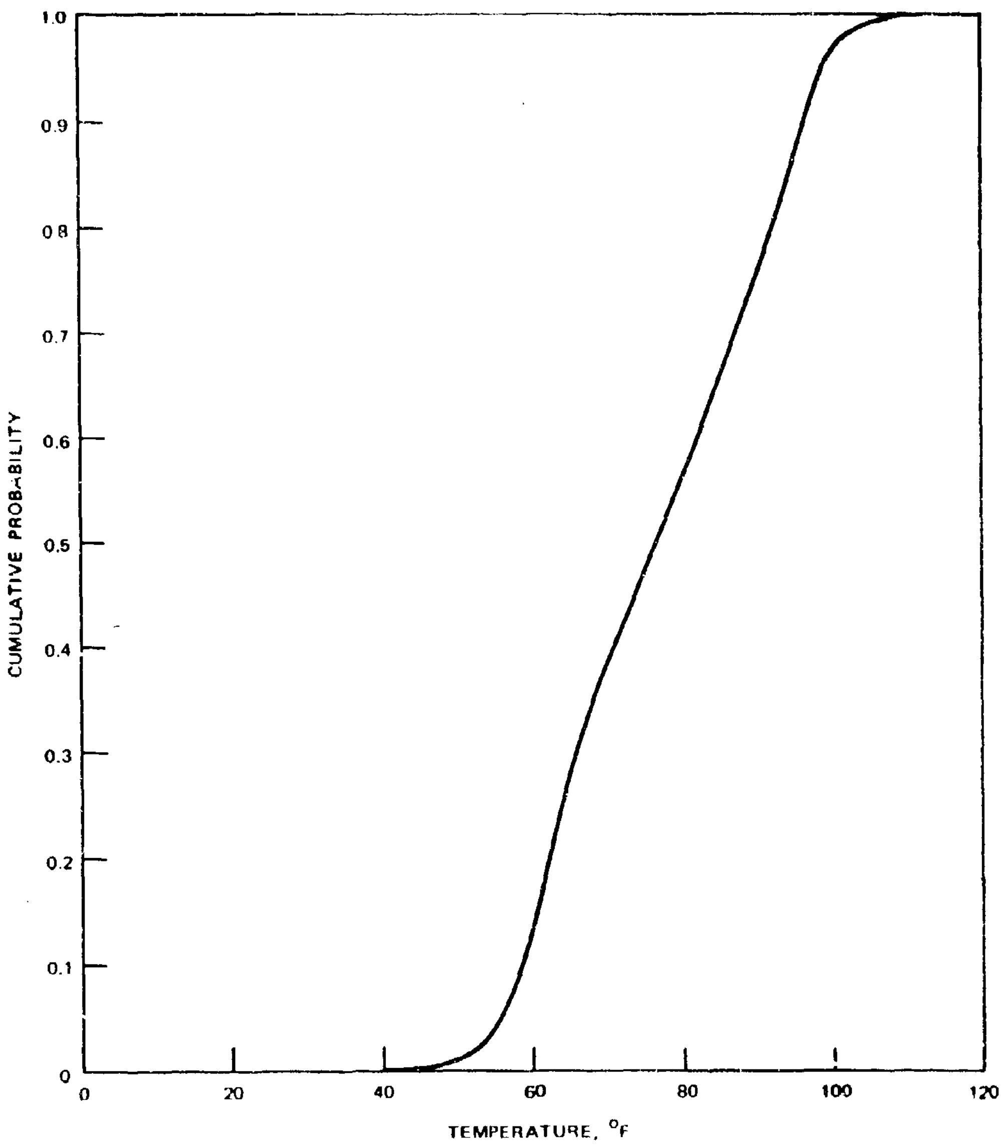


FIG. 1. Yuma, Arizona Minimum and Maximum Air Temperatures.

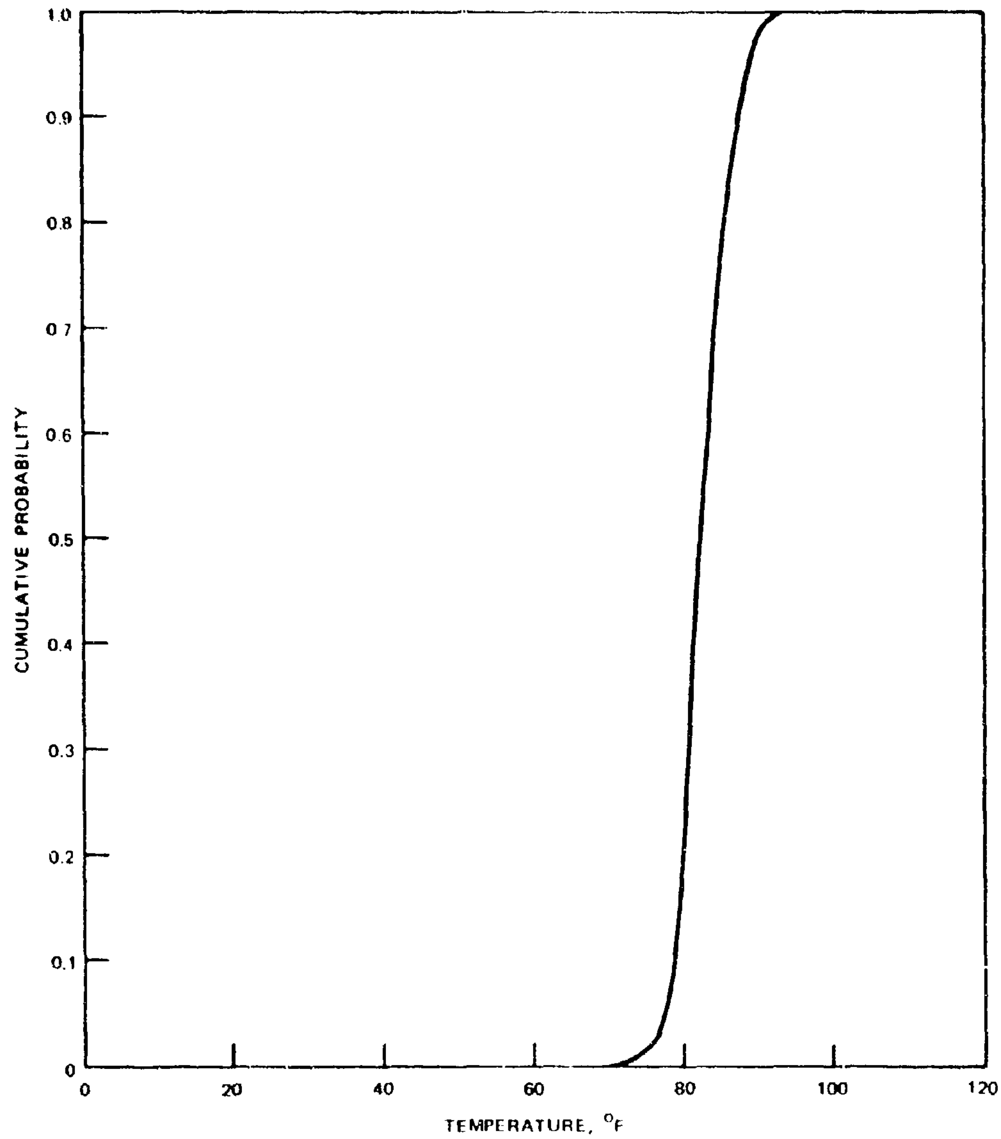


FIG. 2. Subic Bay, Republic of the Philippines Minimum and Maximum Air Temperatures.

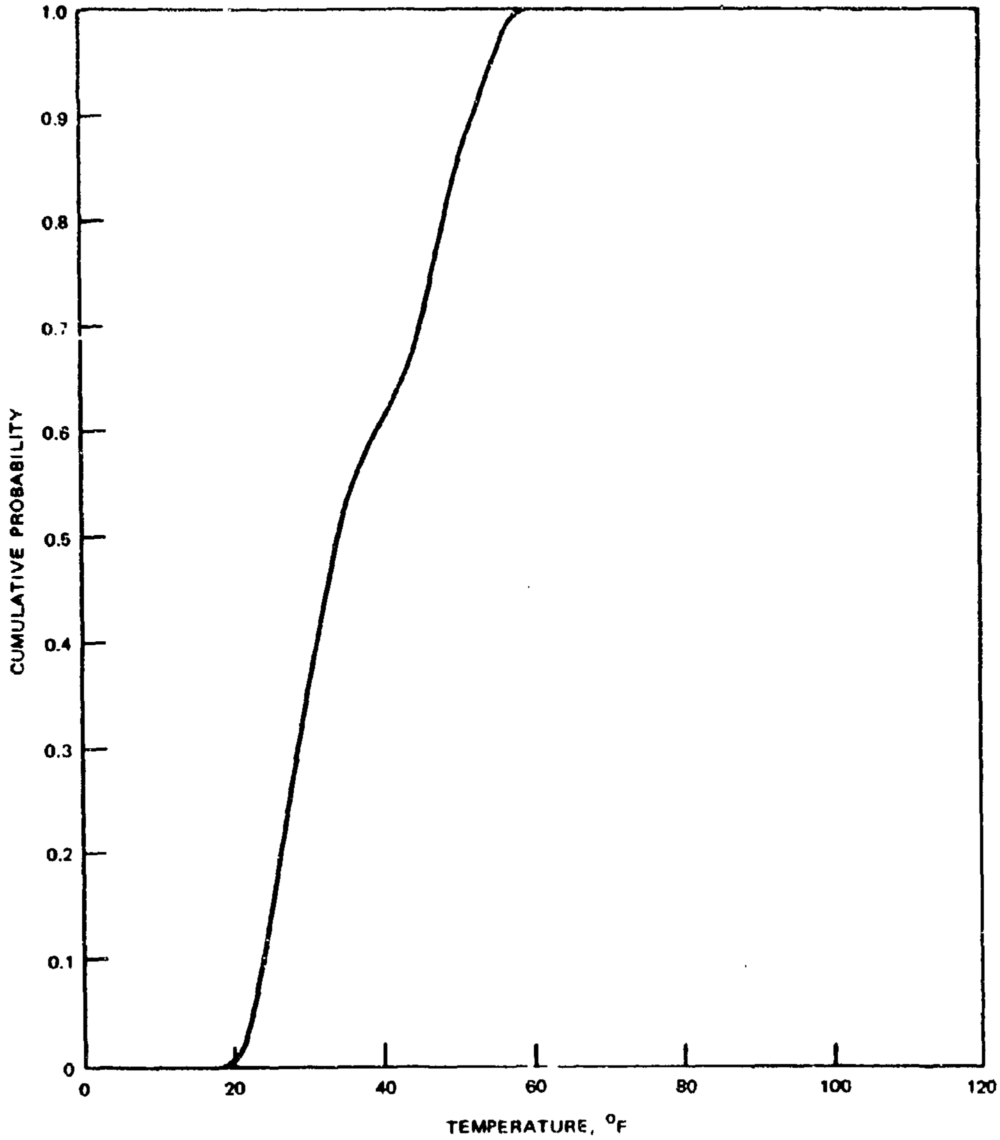


FIG. 3. Fort Richardson, Alaska, Earth-Covered Minimum and Maximum Air Temperatures.

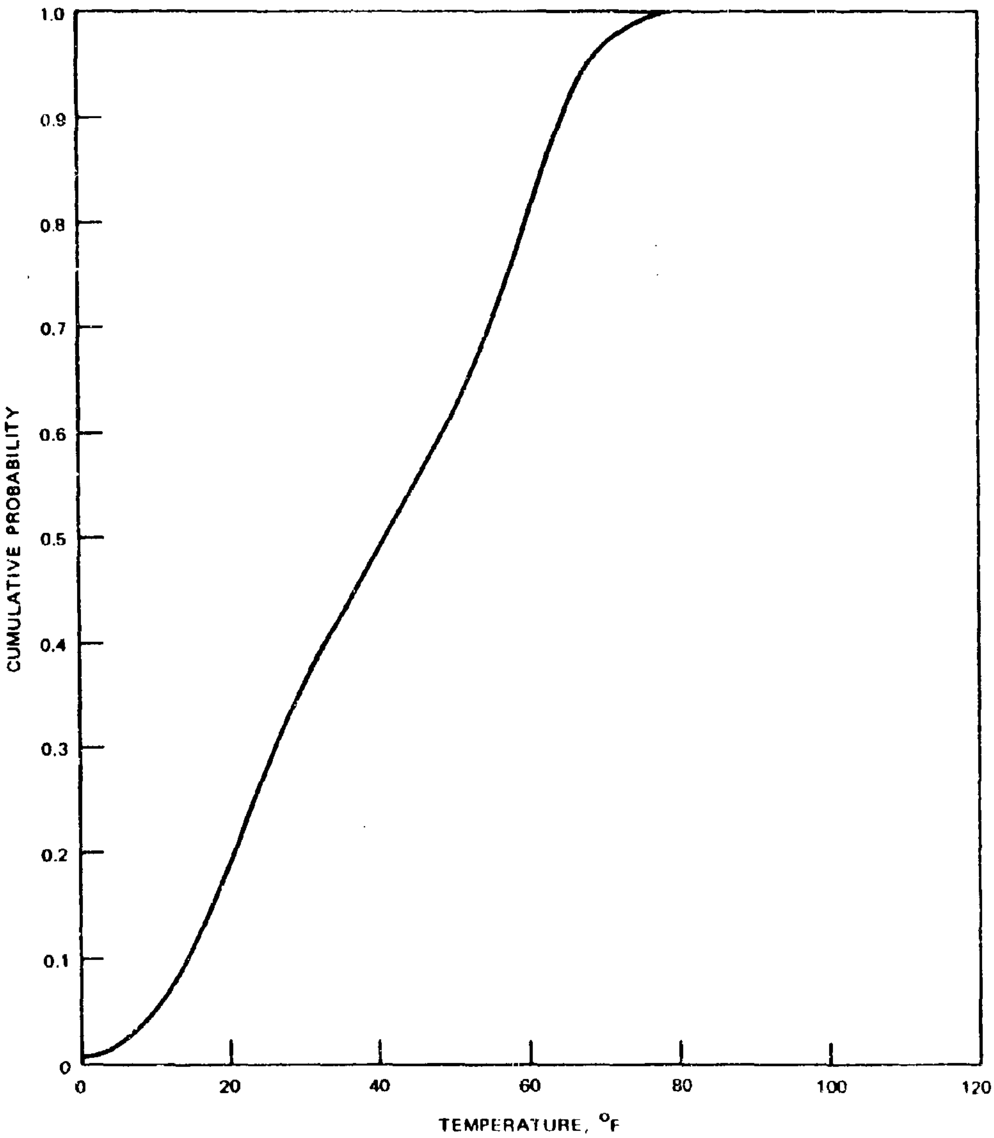


FIG. 4. Fort Richardson, Alaska, Non-Earth-Covered Minimum and Maximum Air Temperatures.

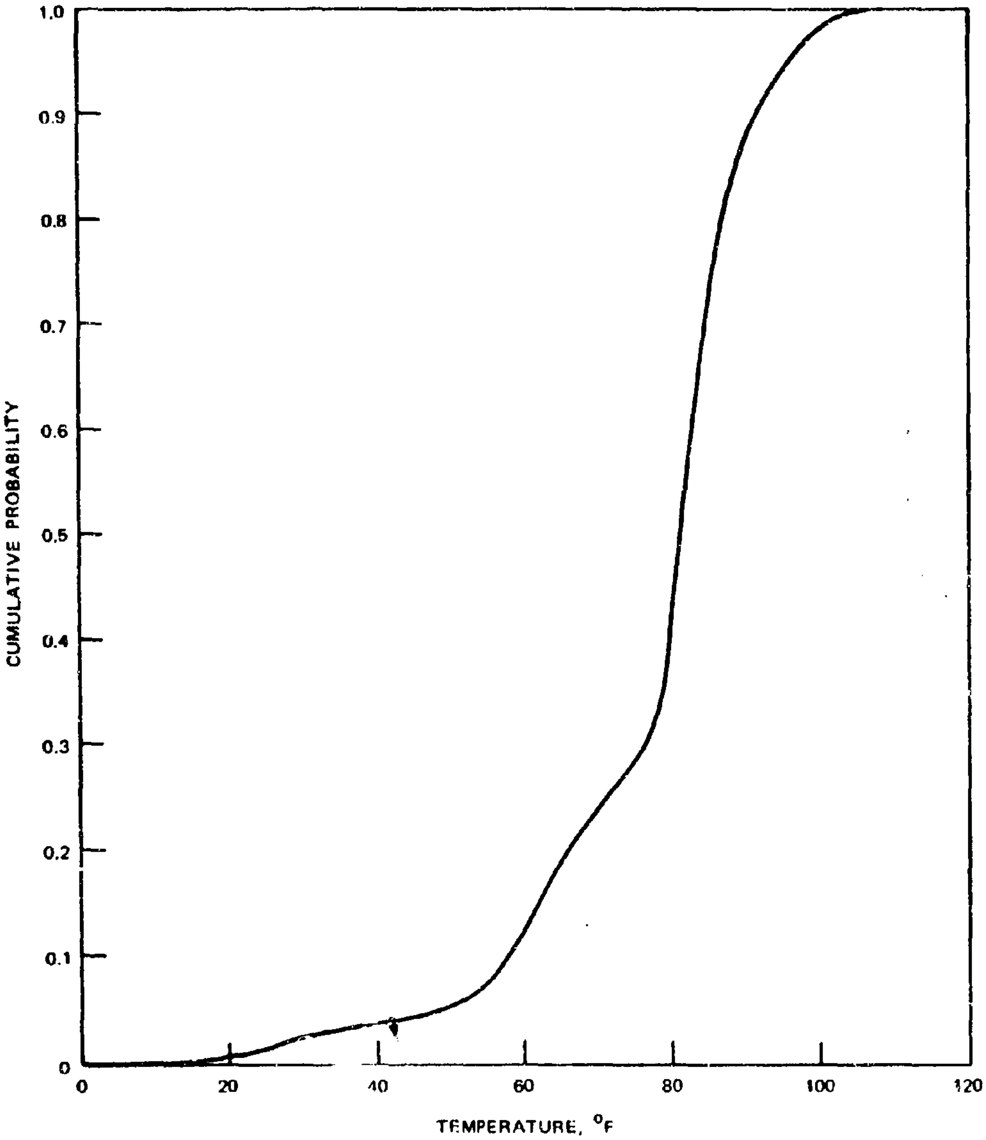


FIG. 5. Composite of Yuma, Subic Bay, and Fort Richardson Minimum and Maximum Air Temperatures.

CONCLUSIONS

The storage temperatures within the existing worldwide igloo and covered storage complex are not as severe as has been previously assumed.

The ordnance in covered storage will not be subjected to air temperatures of less than -9°F and/or more than 117°F on a worldwide basis. The chance of experiencing any temperature value outside of these limits is less than 1 in 80,000, based on the sample of data available.

Figures 1 through 5 can be used to establish upper temperature limits or lower temperature limits for any material that is to be stored in the existing worldwide complexes of the Army and Navy.

Appendix A

DATA HANDLING

The procedure for handling the storage temperature data is as follows:

Step 1. The applicable data are key punched onto IBM type cards from the temperature summary sheets as received from the ammunition storage facility (shown in Table 2).

TABLE 2. Punchcard Data

	Month	Day	Year	Type of magazine	Temp., reading		Storage location
					Low	High	
Example	08	01	66	10LC1	76	79	NAD, Crane
Card Column	3---	-------	-- 8	18-26	36-38	42-44	55-79

Step 2. The punched cards (Step 1) are sorted in the following manner:

a. Storage location: e.g., NAD, Crane

b. Type of magazine: earth-covered or non-earth-covered.

c. Calendar sequence: month, day, and year.

Step 3. The input and output for a computer run are:

a. Input:

(1) Computer program (420-052).

(2) Total card: number of months.

(3) Sorted cards from Step 2.

b. Output:

(1) Averages and standard deviations of maximum and minimum temperatures of each month on cards, as shown in Fig. 6.

(2) Raw data information, as shown on microfilm, Fig. 7.

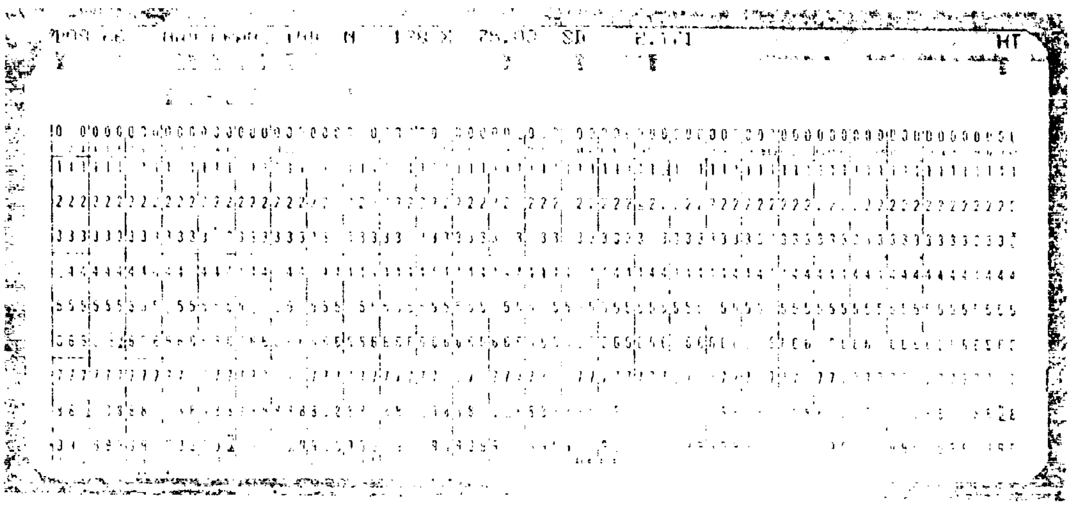


FIG. 6. Typical $\overline{x}$, s Card.

RAW DATA (TEMPERATURES)

NAD CRANE IND

DATE	MAG NO.	LO	HI	DATE	MAG NO.	LO	HI	DATE	MAG NO.	LO	HI	DATE	MAG NO.	LO	HI
080166	10LC1	76	79	080166	10LC2	74	76	080166	222FC30	74	79	080166	225AT20	71	75
080166	225AT2	73	77	080166	225AT3	71	76	080266	18PC68	73	75	080266	18PC69	70	73
080266	222FC33	70	77	080266	205AT17	71	77	080266	205AT19	75	79	080266	205AT20	74	78
080366	32LC1	70	74	080366	32LC2	70	75	080366	222FC43	70	77	080366	244AT16	71	76
080366	244AT19	68	74	080366	244AT20	69	76	080466	35PC2	74	76	080466	35PC	73	77
080466	222FC35	72	78	080466	249AT13	68	71	080466	249AT14	69	71	080466	249AT17	69	72
080566	7PC55	73	75	080566	7PC56	68	73	080566	222FC25	73	76	080566	201AT18	70	76
080566	201AT19	73	77	080566	201AT20	69	75	080866	10LC1	74	78	080866	10LC2	71	75
080866	222FC30	73	79	080866	205AT17	68	73	080866	205AT19	70	75	080866	205AT20	72	77
080966	18PC68	72	76	080966	18PC69	68	73	080966	222FC33	73	79	080966	225AT20	70	75
080966	225AT2	72	77	080966	225AT3	71	75	081066	32LC1	69	74	081066	32LC2	71	76
081066	222FC43	69	74	081066	244AT16	72	76	081066	244AT19	70	75	081066	244AT20	70	74
081166	35PC2	71	75	081166	35PCO	72	77	081166	222FC35	74	78	081166	249AT13	68	73
081166	249AT14	69	74	081166	249AT17	70	73	081266	7LC42	68	71	081266	7LC43	70	73
081266	222FC80	71	78	081266	203AT7	70	75	081266	203AT8	67	72	081266	203AT9	68	72
081566	18LC33	72	75	081566	18LC34	72	76	081566	222FC62	73	77	081566	206AT15	70	76
081566	206AT16	68	74	081566	206AT17	69	75	081666	26PC11	67	72	081666	26PC12	70	73
081666	222FC83	74	78	081666	224AT4	70	73	081666	224AT5	69	72	081666	224AT7	78	71
081766	28LC4	68	73	081766	28LC5	71	74	081766	222FC74	75	80	081766	254AT15	70	73
081766	254AT16	69	72	081766	254AT17	70	75	081866	42LC5	69	71	081866	42LC6	71	74
081866	222FC75	72	78	081866	256AT5	70	75	081866	256AT6	71	76	081866	256AT7	71	75
081966	7LC42	72	76	081966	7LC43	73	77	081966	222FC60	72	79	081966	203AT7	71	78
081966	203AT8	69	77	081966	203AT9	68	77	082266	18LC33	70	73	082266	18LC34	71	74
082266	222FC82	73	80	082266	206AT15	71	77	082266	206AT16	70	76	082266	206AT17	68	75
082366	26PC11	68	74	082366	26PC12	69	75	082366	222FC63	73	80	082366	224AT4	70	75
082366	224AT5	70	73	082366	224AT7	69	73	082466	28LC4	68	74	082466	28LC5	70	73
082466	222FC74	70	78	082466	254AT15	68	71	082466	254AT16	68	73	082466	254AT17	71	73
082566	42LC5	67	70	082566	42LC6	70	73	082566	222FC75	69	76	082566	256AT5	70	74
082566	256AT6	70	75	082566	256AT7	69	74	082666	7LC42	71	75	082666	7LC43	73	76
082666	222FC60	70	76	082666	203AT7	70	77	082666	203AT8	70	76	082666	203AT9	68	75
082966	18LC33	67	72	082966	18LC34	68	73	082966	222FC82	71	77	082966	206AT15	69	75
082966	206AT16	67	75	082966	206AT17	67	74	083066	26PC11	67	72	083066	26PC12	68	73
083066	222FC81	72	78	083066	224AT4	69	74	083066	224AT5	70	74	083066	224AT7	69	76
083166	28LC4	70	74	083166	28LC5	68	75	083166	222FC74	72	77	083166	254AT15	70	73
083166	254AT16	69	72	083166	254AT17	69	74								

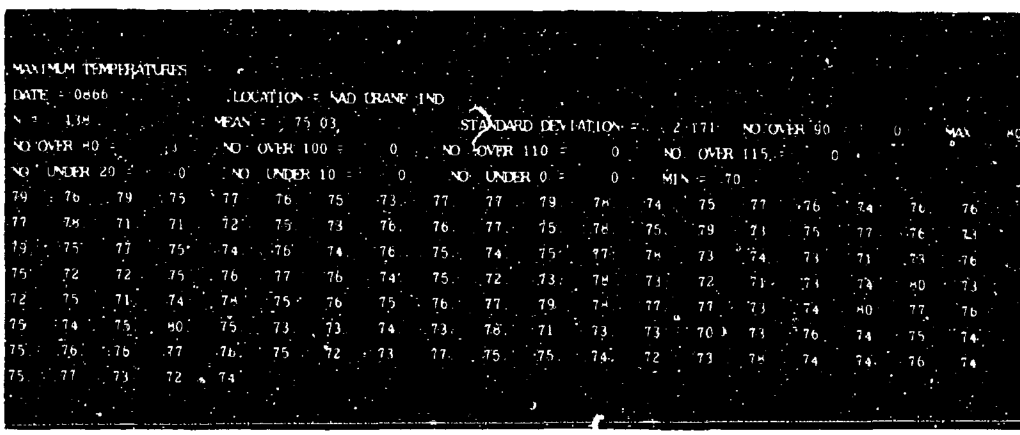
FIG. 7. Raw Data on Microfilm.

(3) Maximum and minimum temperature data for each month. The maximum temperature data labeled "High Temperature," as shown on microfilm, Fig. 8.

(4) Deck of cards which carries the necessary identification for mounting the microfilm on the aperture card.

Step 4. The identification punched into the output decks created in Step 3b(2) and (3), shown in Fig. 9 and 10, are cut into segments and mounted on aperture cards.

Step 5. The output deck (Step 3b(1)) is assembled for the computer program (420-053) and fed into the Univac 1108 computer. The output is a curve plot which gives average maximum and minimum temperatures for the effective dates of output deck data retention. A microfilm of the curve is produced and mounted on an aperture card.


MAXIMUM TEMPERATURES
DATE = 0866 LOCATION = NAD CRANE IND
N = 138 MEAN = 75 03 STANDARD DEVIATION = 2 171 NO OVER 90 = 0 MAX 80
NO OVER 80 = 3 NO OVER 100 = 0 NO OVER 110 = 0 NO OVER 115 = 0
NO UNDER 20 = 0 NO UNDER 10 = 0 NO UNDER 0 = 0 MIN = 70

79	76	79	75	77	76	75	73	77	77	79	78	74	75	77	76	74	76	76
77	78	71	71	72	75	73	76	76	77	75	78	75	79	73	75	77	76	73
79	75	77	75	74	76	74	76	75	74	75	77	78	73	74	73	71	73	76
75	72	72	75	76	77	76	74	75	72	73	78	73	72	71	73	74	80	73
72	75	71	74	78	75	76	75	76	77	79	78	77	77	73	74	80	77	76
75	74	75	80	75	73	73	74	73	78	71	73	73	70	73	76	74	75	74
75	76	76	77	76	75	72	73	77	75	75	74	72	73	78	74	74	76	74
75	77	73	72	74														

FIG. 8. Data on Microfilm.

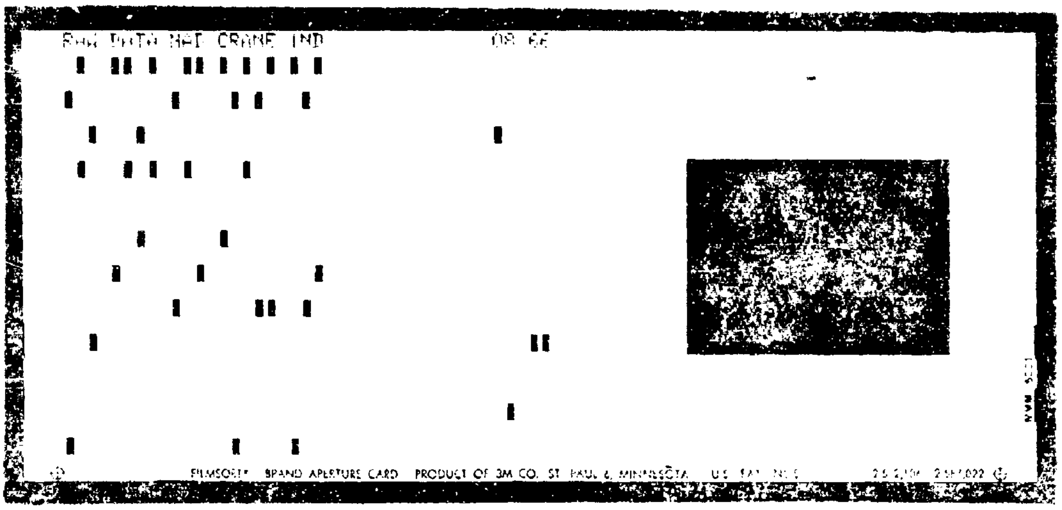


FIG. 9. Aperture Card With Microfilm Insert of Raw Data Shown in Fig. 7.

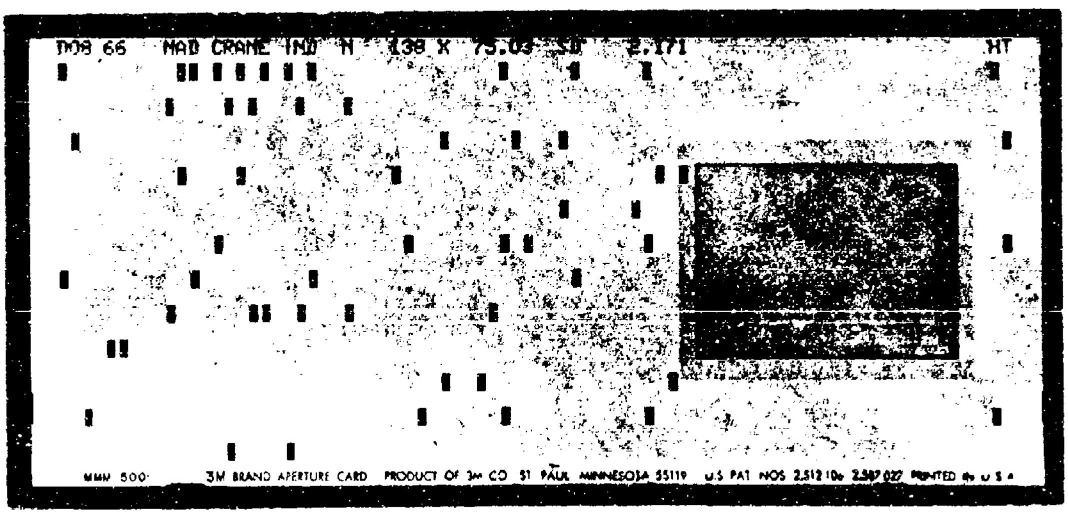


FIG. 10. Aperture Card With Microfilm Insert of Data Shown in Fig. 8.

Appendix B

TEMPERATURE MEASUREMENTS WITHIN AN EARTH-COVERED MAGAZINE

As stated in the main body of this report, most of the thermometers used in obtaining the air temperature data were located on the inside wall of the entrance. In order to provide an indication of how air temperatures at various locations within the magazine, as well as temperatures of ordnance stored in the magazine, would compare with measurements taken with the horseshoe thermometer mounted on the inside wall of the entrance, a storage magazine at NWC was instrumented as follows:

Thermocouple No.	Location
1	In the center of a bandoleer of 7.62 mm NATO ammunition
2	On top of a metal box lid of 7.62 mm NATO ammunition
3	Under 1/4-inch of tar covering the dirt on top of the magazine
4	On the inside wall of an aluminum Sidewinder guidance and control (G&C) shipping container
5	On the outside wall of a Sidewinder G&C section
6	One-half inch away from the horseshoe thermometer mounted on the inside front wall about 4 1/2 feet above the floor
7	On the inside wall of the lowest roof of the double roofed recorder box (outside the magazine)
8	Inside the Model 15 recorder on the thermocouple junction input board

The measurements were taken during 2 days in August, 1971. The results at 30 minute intervals are given in Table 3. A plot of the data from thermocouples 1, 2, 3 and 6 is presented in Fig. 11. As can be noted, even though the dirt temperature on top of the magazine varied from 81 to 137°F, the air temperature in the magazine remained relatively stable. Also, the ordnance temperatures were within ±4°F of the magazine air temperature.

TABLE 3. Total Data Log, Temperature - °F.

Thermocouple No.							
1	2	3	4	5	6	7	8
92	95	128	94	93	93	117	119
92	95	131	93	92	92	118	125
92	95	133	94	92	92	115	130
92	95	137	94	93	93	121	133
91	95	135	94	92	92	121	136
91	96	127	94	92	92	120	137
92	96	123	94	92	93	118	138
90	95	116	93	91	91	117	137
90	95	111	93	91	91	114	136
90	95	106	93	91	91	111	135
91	95	101	93	92	92	106	132
92	96	98	94	93	93	103	130
93	96	95	95	94	94	101	128
92	95	93	94	94	93	100	125
93	95	91	95	94	94	98	123
93	95	91	95	94	94	97	122
92	94	89	94	93	93	96	120
94	94	88	93	93	92	95	118
93	95	89	95	95	93	95	117
92	94	87	95	95	94	94	117
92	93	85	93	93	92	92	113
93	95	84	95	94	94	94	115
94	95	83	95	94	94	93	115
94	95	81	95	95	94	92	114
94	95	82	95	95	94	93	114
94	95	87	95	95	94	96	114
93	94	94	95	94	94	100	114
93	95	102	95	94	94	105	117
93	95	103	96	94	94	108	121
91	93	109	93	92	92	111	124
92	94	124	94	93	93	118	128

TABLE 3. (Contd.)

Thermocouple No.							
1	2	3	4	5	6	7	8
93	95	134	96	94	94	124	132
90	93	133	92	91	91	114	132
90	93	135	92	91	91	120	135
90	93	132	92	91	91	123	137
90	94	125	93	91	91	122	136
90	94	123	93	91	91	124	137
90	94	112	93	91	91	116	138
90	94	106	93	91	91	110	136
91	94	102	93	92	92	107	133
91	94	98	93	92	92	103	131
91	94	96	93	91	91	101	128
91	93	93	93	92	92	101	126
91	93	91	93	91	91	99	124
91	93	87	93	92	92	98	123
91	93	86	93	92	92	96	121
91	93	85	93	92	92	97	120
91	93	84	93	92	92	96	119
91	93	85	93	92	92	97	119
91	93	85	93	92	92	96	118
91	93	86	93	92	92	95	118
91	93	84	93	92	92	94	117
91	93	83	93	92	92	93	116
91	92	82	92	91	91	91	115
91	92	82	92	91	91	94	114
90	92	86	92	91	91	96	115
90	92	90	92	91	91	100	114
90	92	99	92	91	91	104	118
90	93	107	93	91	91	108	121
91	93	112	93	91	91	111	124
91	94	113	93	91	91	112	127
90	94	121	93	91	91	116	129
90	94	120	93	91	91	118	132

TABLE 3. (Contd.)

Thermocouple No.							
1	2	3	4	5	6	7	8
90	94	134	93	91	91	125	135
90	94	130	93	91	91	127	137
90	93	126	93	91	91	130	140
90	93	131	92	91	91	125	142
90	93	119	92	91	91	121	143
90	93	106	92	91	91	115	141
90	94	104	93	91	91	112	138
91	94	99	93	91	91	104	134
91	94	94	93	92	92	102	130
91	94	92	93	92	92	100	128
91	94	88	93	92	92	99	125
91	93	88	93	92	92	97	123
91	93	87	93	92	92	98	121

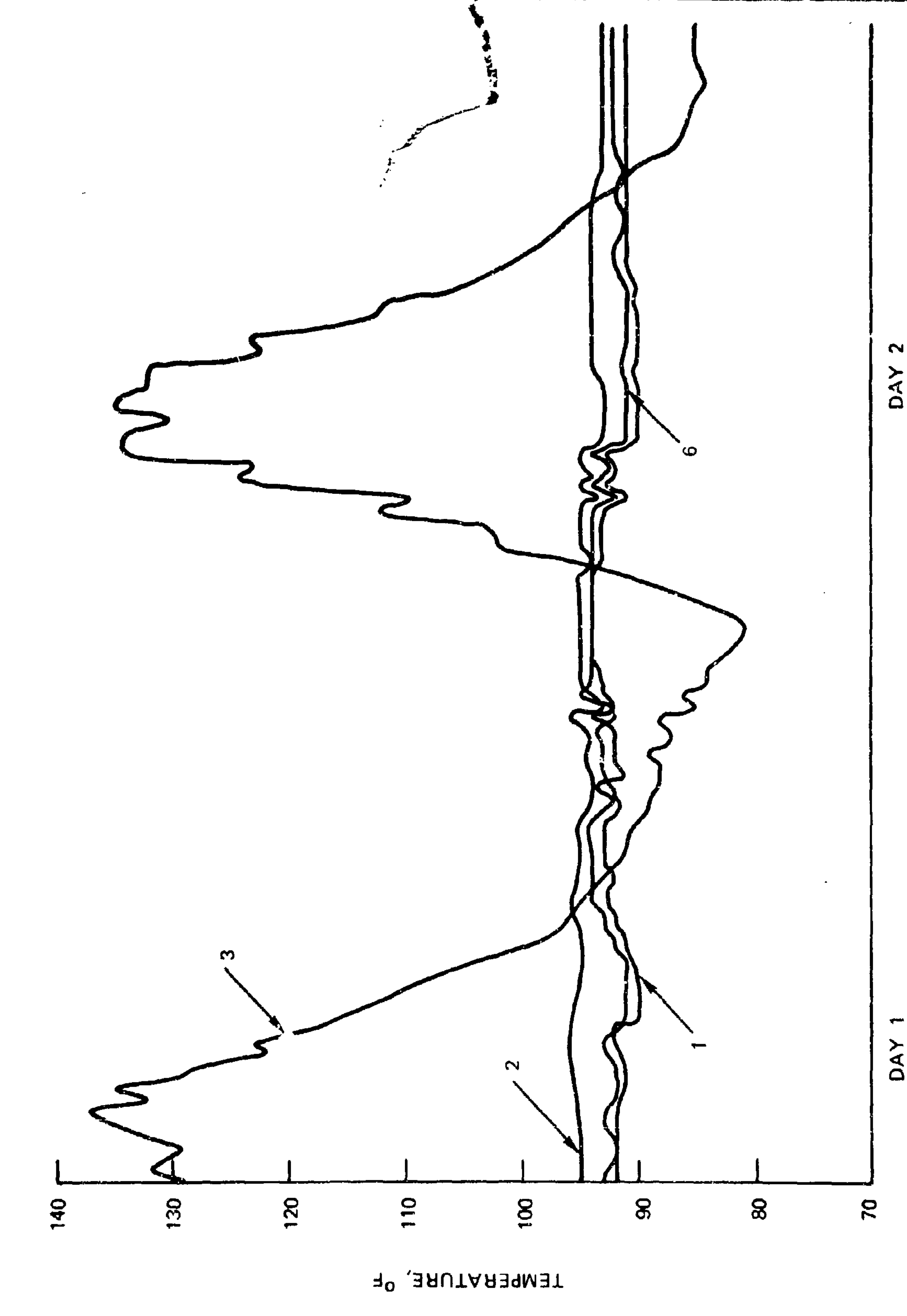


FIG. 11. Plot of Data From Thermocouples 1, 2, 3 and 6.

Appendix C

CONSTRUCTION OF CUMULATIVE DISTRIBUTION CURVES

The imput data are minimum and maximum air temperature readings from storage magazines. The frequency distribution of the minimum and maximum air temperatures may be unimodal, uniform, bimodal, or skewed to the right or left. Figure 12 is an example of an air temperature frequency distribution curve. The frequency distribution curves depict the spread and frequency of the observed values. In Fig. 12, the spread of the observed values is between the minimum observed value T_1 and the maximum observed value T_2, and the frequency or number of observations around T_3 is greater than around T_1, T_5, T_4, or T_2.

Figure 13 is a representative cumulative distribution curve that can be constructed from the frequency distribution curve of Fig. 12. The cumulative distribution curve is constructed by plotting the summed observations from the minimum temperature value ascending in magnitude to the maximum temperature value. Usually the total number of observations (N) is normalized to unity $(\frac{N}{N})$ so that the values of the cumulative distribution curve take on proportions such as $\frac{1}{N}, \frac{2}{N}, \frac{5}{N}, \ldots, \frac{N-3}{N}, \frac{N}{N}$. For example, if the observations are 3, 4, 4, 4, 5, 6, the proportions would be $\frac{1}{6}, \frac{4}{6}, \frac{5}{6}$, and $\frac{6}{6}$, where the observed values are 3, 4, 5, and 6 respectively, as shown in Fig. 14. The proportion P_i in Fig. 13 is the probability (P_i) that an observation will take on a value equal to or less than T_i. It can also be seen in Fig. 13 that the probability that an observation takes on a value equal to or less than T_1 is P_1, the probability that an observation takes on a value greater than T_2 is $1 - P_2$, and the probability that an observation takes on a value that is somewhere between T_1 and T_2 is $P_2 - P_1$.

Suppose that the minimum temperature are 71, 70, 74, 76, 72, 72, 73, 70, 71, 73 and the corresponding maximum temperatures are 80, 81, 82, 83, 83, 80, 82, 83, 84, 80 respectively. Then the cumulative distribution curves for the minimum and maximum temperatures can be constructed as shown in Fig. 15, where the minimum and maximum temperatures are labeled A and B respectively. If the minimum and maximum temperature values are lumped together, the cumulative distribution curve is shown as curve C. Curve C is biased; it shows the probability (or expected duration in percent) that the temperature will be near the minimum or maximum to be greater than it actually is because temperatures between maximum and minimum (77, 78, and 79°F) are not accounted for. The curves shown in Fig. 1 through 5 were constructed in the same manner as curve C.

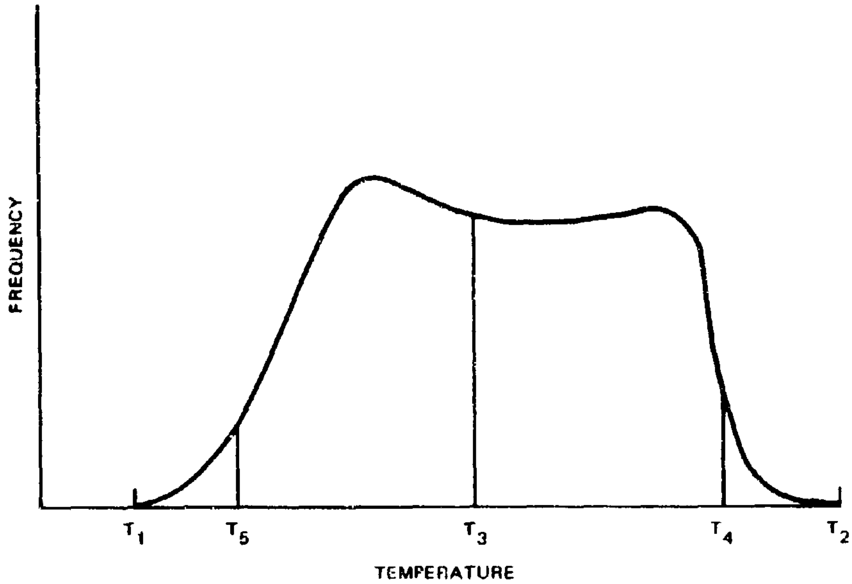


FIG. 12. Example of a Frequency Distribution Curve.

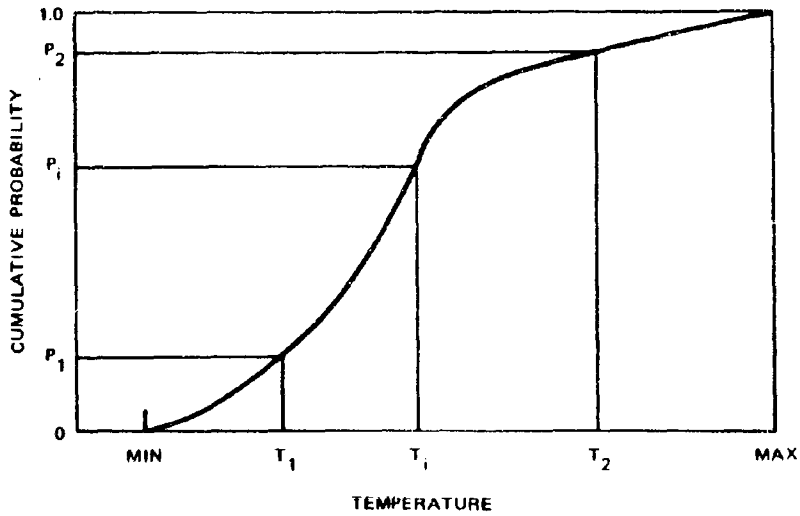


FIG. 13. Example of a Cumulative Distribution Curve.

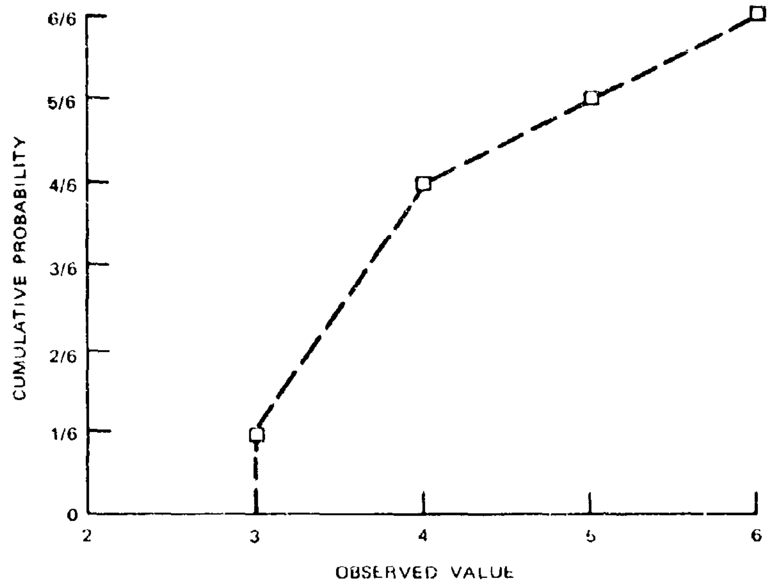


FIG. 14. Example of Cumulative Distribution Curve.

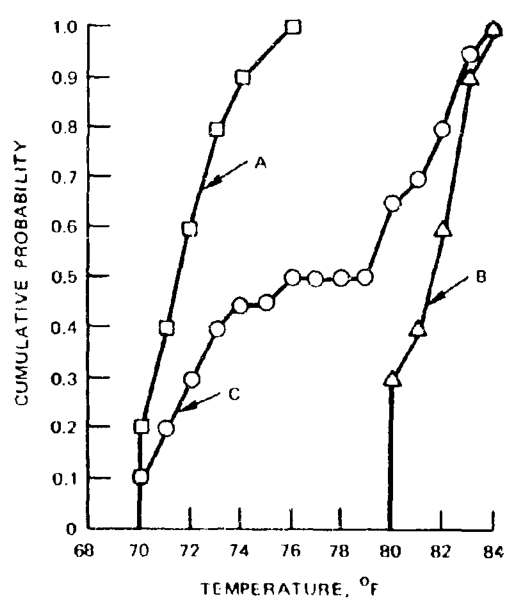


FIG. 15. Cumulative Distribution Curves for Minimum, Maximum, and Combined Minimum and Maximum Temperatures.

Therefore, if the cumulative curve is used to make predictions such as "the probability the temperature will be lower than 45°F and/or higher than 95°F is 0.10," the predictions are conservative, meaning that in this case the 0.10 should be a lower value. Also, since temperatures between minimum and maximum are not accounted for, the probabilities about the 0.50 point (± 0.35) may be in gross error and should not be used.

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Minimum and maximum temperatures (385,221 data points) from explosive hazard storage magazines located at Yuma, Arizona; Subic Bay, Philippines; and Fort Richardson, Alaska are used to construct cumulative distribution curves. These distribution curves show the probability that ordnance, stored in these magazines, will reach any given air temperature. They allow an objective judgment to be made on maximum and minimum earth-covered storage magazine temperature specifications.

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